Taxonomically driven recognition of features for visual categorisation of zooplankton

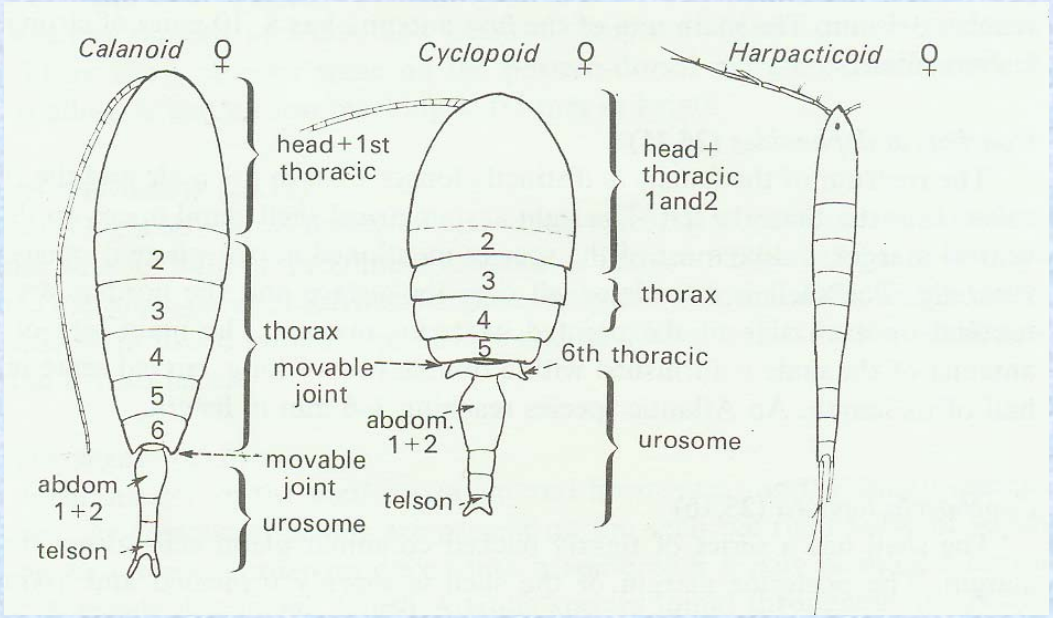
Phil Culverhouse (University of Plymouth, UK.)
Bob Williams (Plymouth Marine Laboratory,UK.)
Isabella Buttino (Stazione Zoologica ‘A Dohrn’, IT)

Humans still out perform machine recognition on digital images

- Why?
  - Machine learning requires large clusters of data
    - Unbalanced data set size is an issue
  - Recognition relies on 2D image features
    - Sensitive to aspect of object
- Solution is 3D

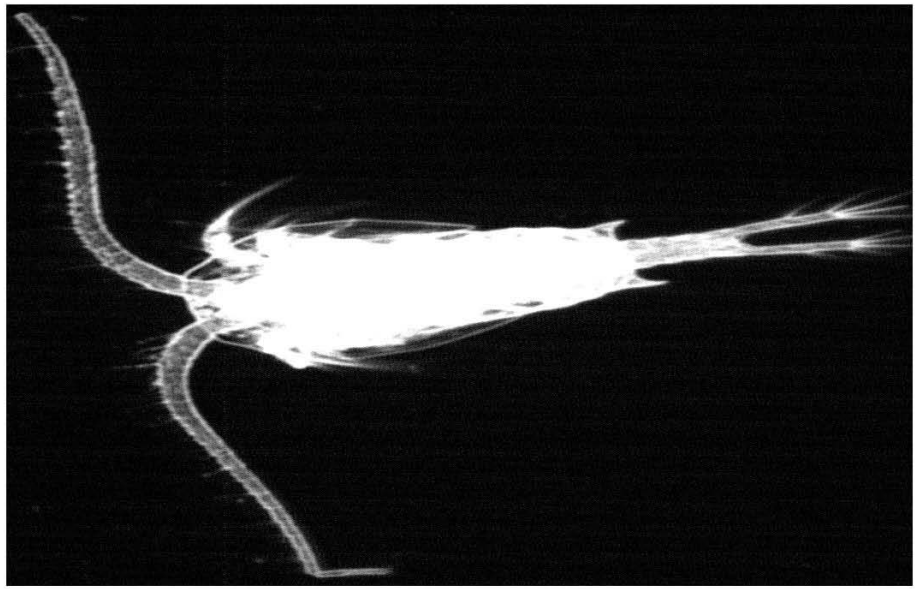
How experts do it

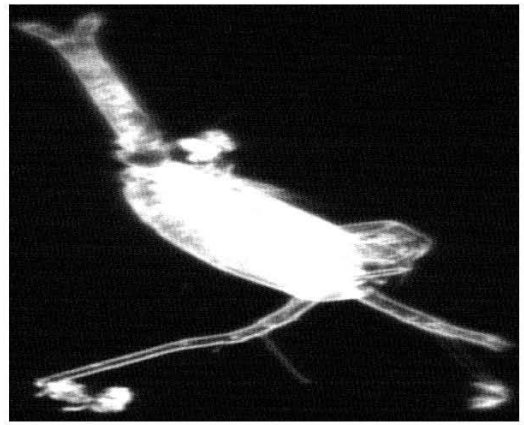
- Zooplankton can be identified using taxonomic information
- Plus contextual data
- & short cuts



Sample taxonomic key data for planktonic copepods
– differences in the segmentation of the body

Recognising zooplankton





- Recognising zooplankton to genera is difficult with lack of information

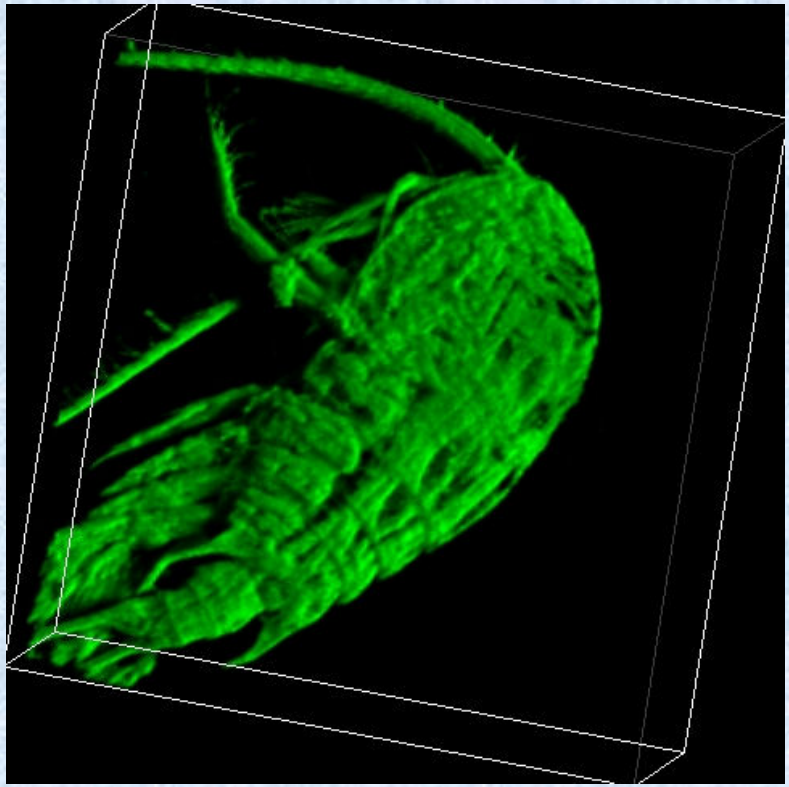
Confocal can provide good reference images

- Confocal image *Temora stylifera: male stage 6*
- *Image quality is sufficient for taxonomy*
- *An image stack provides 3-D information*

Temora stylifera. (source: Buttino, Bay of Naples IT., imaged by confocal)

Confocal

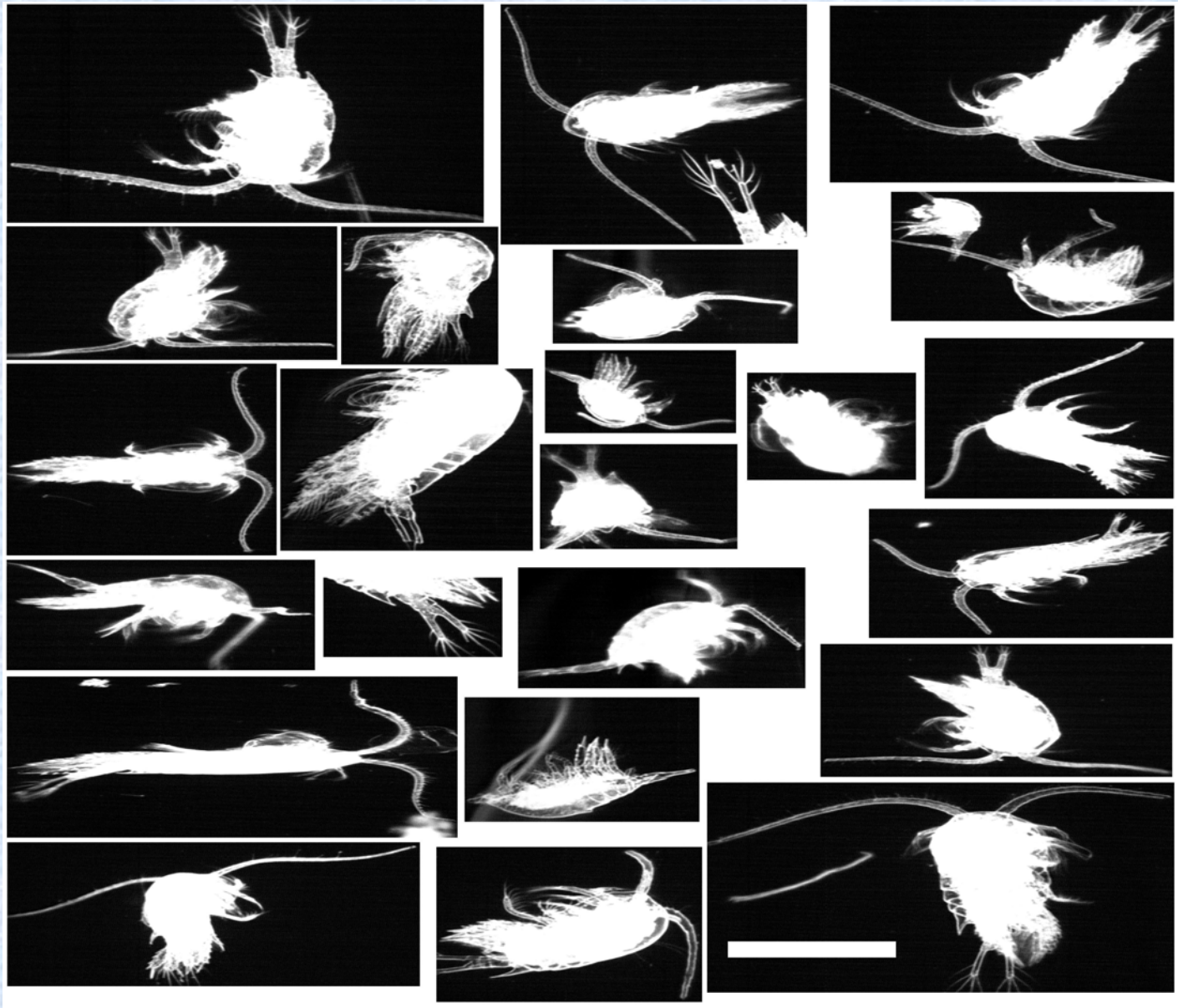
- Volumetric image
  - Reveals structure



3D image of Temora stylifera.
(source: Buttino, Bay of Naples IT.)

Problems

- Next slide shows how a plankton analyst can identify *Temora stylifera*
- Demonstrates the severe problems a machine program would have
  - ie., part image, overlapping images, elongated image, ventral, dorsal aspects,
  - development stages, male and females copepods (morphologically different) etc etc.



Temora stylifera. Scale bar 500 micron (source: Buttino, Bay of Naples IT., imaged by MIA-1)

In-situ imaging

- Fast and sample high volume
- High specimen count
- Clutter, detritus (coastal seas)
- Arbitrary view angle
- Feature visibility is variable
  - Taxonomic identification therefore variable
- Contextual data available

Process Flow diagram

- Taxonomic features are identified
- Features can be taken from preserved specimens
- IKBS system directs search for features in image data

Automatic image analysis of plankton. Culverhouse et. al (2006) MEPS (312) pp. 297-306

Generative models

- Extract features from training data
- Accumulate statistics of occurrence
- Build models of objects
- Assess models on unseen data

- Bottom-up (data driven) inference
- Similar to ANN approaches, but more flexible

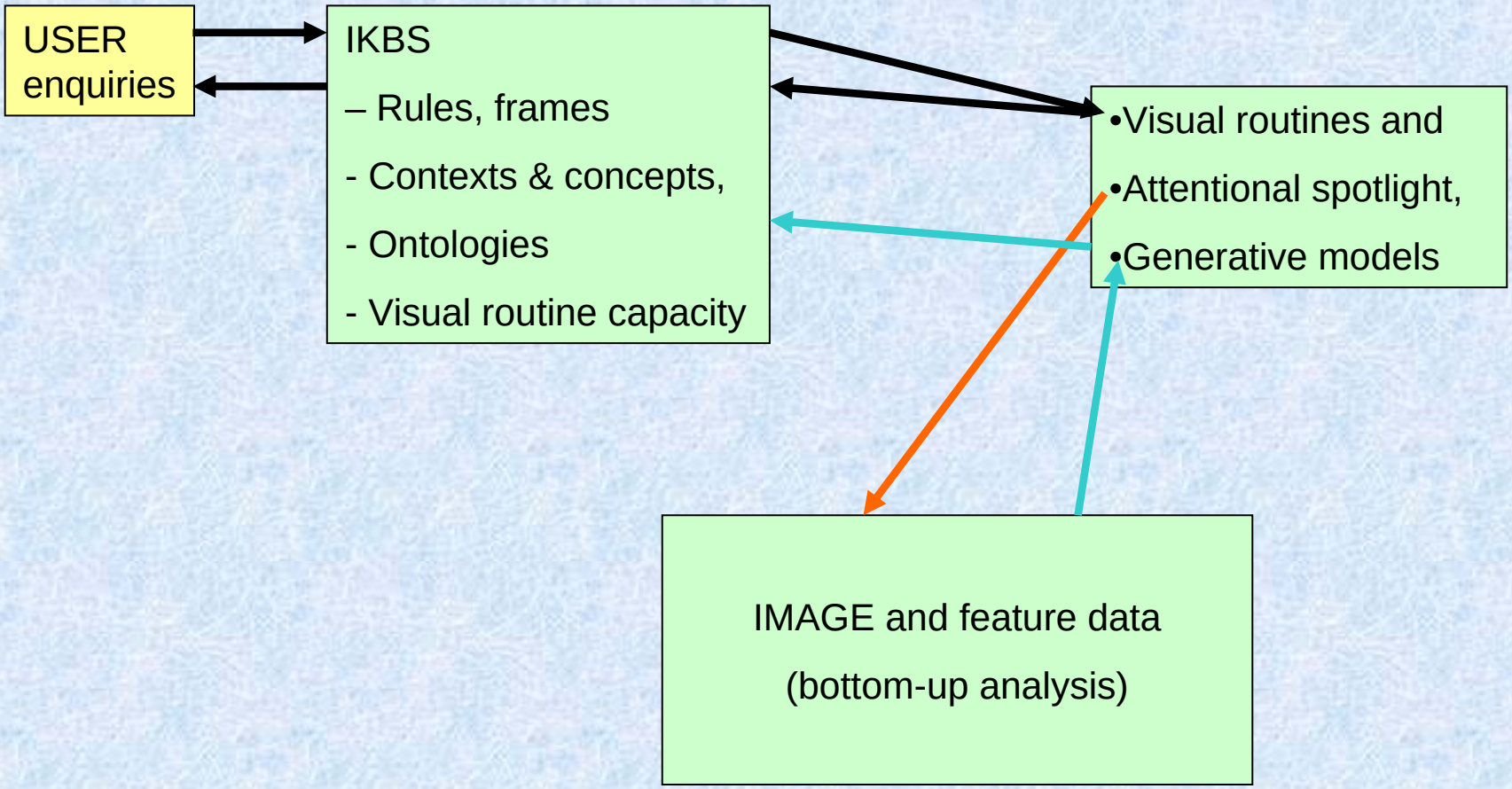
Conceptual models

- Extract knowledge from texts and humans
- Organise into rules, frames and logics
- Validate Knowledge-based system
  - Conflict resolution
  - Incorrect assumptions
- Pose queries to test KBS

In-effective systems

- Generative models cannot easily take contextual knowledge as they are build directly from data, and its frequency of occurrence
- Conceptual models cannot easily operate on noisy real-world images
- A hybrid approach is needed.

A hybrid approach



Hierarchical decisions

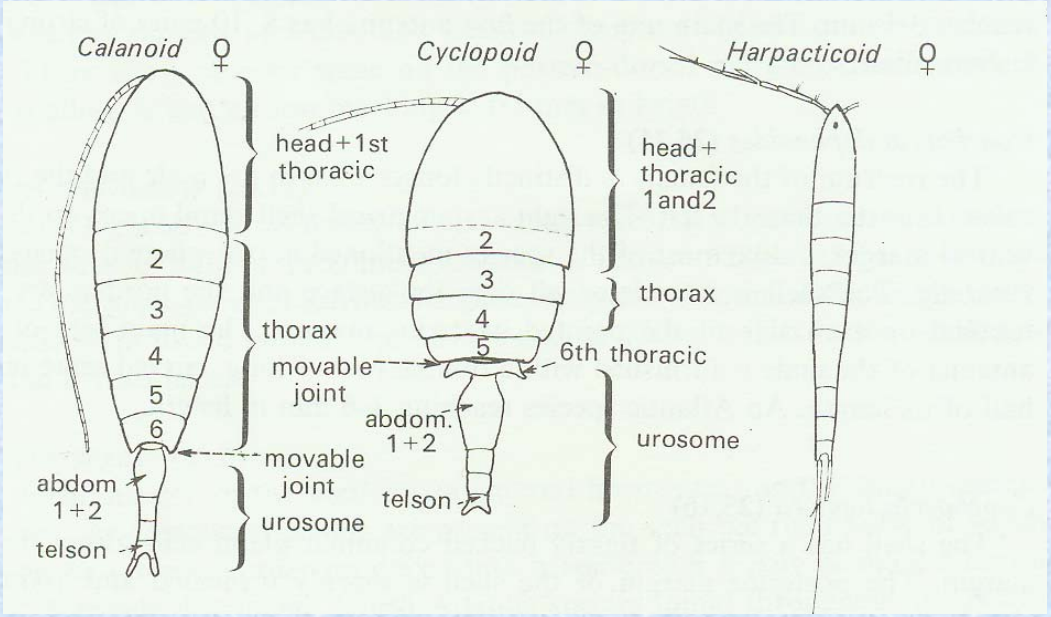
- Use taxonomic tree
  - Scales well with complexity
  - Well documented set of key features
- Use contextual information to constrain search
  - Net mesh size
  - Geographical location, season, etc.

•**Example:**

Phylum Arthropoda
Subphylum Crustacea
Class Maxillopoda
Subclass Copepoda
Order Calanoida
Family Temoridae
Genus *Temora*
species *stylifera*

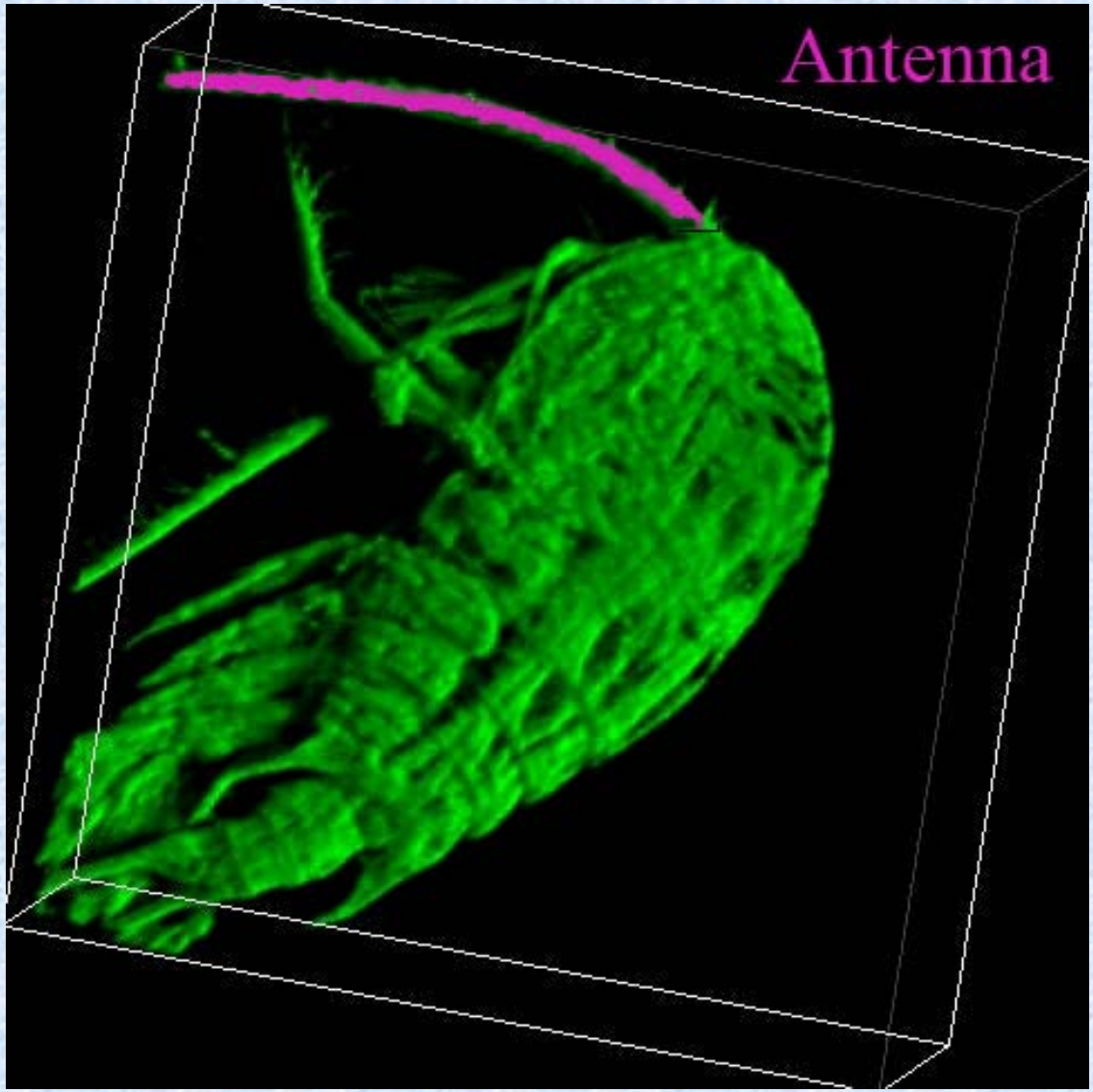
Ontologies

- An ontology is a formal specification of a conceptualization (Gruber 1993).
- An ontology contains the concepts that are assumed to exist in some area of interest and the relationships that hold among them.
- Ontologies are designed for the purpose of knowledge sharing, alignment and reuse.



Sample taxonomic key data for planktonic copepods – differences in the segmentation of the body

- Expert:
  - Highlight part
  - Extract 3D
  - Label antenna



Visual routines

- An IKBS can reason and model the concepts of plankton genera and species
- IKBS poses questions to visual routines
- Visual features present in images need matching
  - Visual routines tuned to specific features discover locations in image
  - Spotlight of attention directs visual routines

A route to cognitive vision

- Generative models with geometric distributions are the current state of art in machine vision
- Texture, morphological features and shape based analysis are predominant in marine and terrestrial specimen identification
- Cognitive vision provides a way of adding
  - More contextual &
  - Taxonomic knowledge to bear on recognition
  - One-shot learning

Progress

- Collecting, imaging and labelling datasets
  - done
- 3D Visual editor for feature extraction
  - In progress
- Ontologies for taxonomy
  - In progress
- Ontologies for low-level vision
  - In progress
- Cognitive system
  - Call for partners for FP7 collaborative project